PATENT ABSTRACTS OF JAPAN

(11)Publication number : 11-274079
(43)Date of publication of application : 08.10.1999

(51)Int.CI. H01L 21/20
H01L 21/203
H01L 21/205

(21)Application number : 10-079857
(22)Date of filing : 26.03.1998

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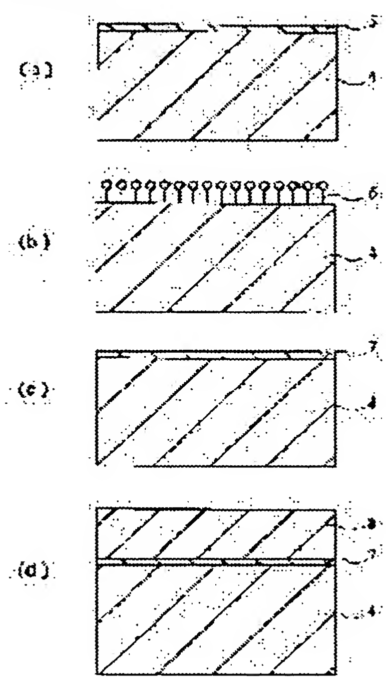
(54) SEMICONDUCTOR DEVICE AND MANUFACTURE THEREOF



(57)Abstract:
PROBLEM TO BE SOLVED: To obtain a high-quality intermediate layer (buffer layer) which permits epitaxial growth of a thin film of high-quality crystalline nitride semiconductor on an inexpensive Si substrate.
SOLUTION: An Si substrate 4 is dipped in, for example, a 1% HF aqueous solution and chemically cleaned to remove a natural oxide film 5 from a surface of the Si substrate 4 and form a hydrogen end face 6. Next, the Si substrate 4 is loaded in a molecular beam epitaxy(MBE) system and heated at about 900° C for 15 minutes in an ethanol (C2H5OH) atmosphere of about 10-6 Torr, thereby forming a monocrystalline SiC thin film 7 with a thickness of about 2 nm on the surface of the Si substrate 4. Then, a GaN film 8 is epitaxially grown to a thickness of 50 nm at a substrate temperature of 600° C for a 1-hour reaction time by the MBE using, for example, organic gallium gas and ammonia (NH3) as source gases.

LEGAL STATUS

[Date of request for examination] 26.03.1998

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]	2927768
[Date of registration]	14.05.1999
[Number of appeal against examiner's decision of rejection]	
[Date of requesting appeal against examiner's decision of rejection]	
[Date of extinction of right]	

CLAIMS

[Claim(s)]
[Claim 1] It is the semiconductor device characterized by being what controls amorphous-ization by nitriding of said silicon substrate in the case of said epitaxial growth while it is the semiconductor device which has the silicon substrate which consists of single crystal silicon, the interlayer formed on said silicon substrate, and the nitride semi-conductor layer by which epitaxial growth was carried out on said interlayer and said interlayer eases the lattice constant difference of said silicon substrate and a nitride semi-conductor layer.
[Claim 2] It is the semiconductor device which is a semiconductor device according to claim 1, and is characterized by said interlayer being the carbonization silicon film or silicon germanium film which has the crystal structure.
[Claim 3] It is the semiconductor device which is a semiconductor device according to claim 1 or 2, and is characterized by said interlayer's thickness being 10nm or less.
[Claim 4] The semiconductor device characterized by having which structure of 2nd structure ** whose crystal structure of said interlayer and a nitride semi-conductor layer it is a semiconductor device according to claim 1, 2, or 3, the front face of said silicon substrate is an equivalent front face as physically as a field (100), the 1st structure where the crystal structure of said interlayer and a nitride semi-conductor layer is cubic system, or the front face of said silicon substrate is an equivalent front face as physically as a field (111), and is hexagonal system.
[Claim 5] It is the semiconductor device which is a semiconductor device given in any 1 term of claims 1-4, and is characterized by the lattice constant difference of said interlayer and a nitride semi-conductor layer being 5% or less.
[Claim 6] The manufacture approach of the semiconductor device characterized by forming the single crystal thin film which eases the lattice constant difference of said substrate and said nitride semi-conductor layer on the principal plane of said substrate as pretreatment of the process which carries out epitaxial growth of the nitride semi-conductor layer on the substrate which consists of single crystal silicon.
[Claim 7] It is the manufacture approach of the semiconductor device characterized by being the manufacture approach of a semiconductor device according to claim 6, and forming said single crystal thin film by heat-treating said substrate in the ambient atmosphere of the gas which consists of a molecule containing a carbon atom or a germanium atom, and a hydrogen atom.
[Claim 8] The manufacture approach of the range whose temperature of said substrate it is the manufacture approach of a semiconductor device according to claim 7, and is 700 degrees C - 1300 degrees C about the conditions of said heat treatment, and the semiconductor device characterized by making the processing time into the range of 1

second - 1 hour.
[Claim 9] The manufacture approach of the semiconductor device which is the manufacture approach of a semiconductor device given in any 1 term of claims 6-8, and is characterized by processing said substrate with the acidic solution containing hydrogen before formation of said single crystal thin film.
[Claim 10] It is the manufacture approach of the semiconductor device characterized by being the manufacture approach of a semiconductor device given in any 1 term of claims 6-9, and forming said nitride semi-conductor layer using the molecular-beam-epitaxy method which used the halide gaseous-phase epitaxy method, the organic metal chemical reaction grown method, the organic metal molecular-beam grown method, or the source of a nitrogen radical.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention is applied to the technique to which heteroepitaxial growth of the large nitride compound semiconductor layer of a lattice constant difference with a substrate is carried out especially about a semiconductor device and its manufacturing technology, and is effective.
[0002]
[Description of the Prior Art] For example, the nitride semi-conductor attracts attention as an ingredient applicable to light emitting diode (LED:Light Emitting Diode), semiconductor laser (LD:Laser Diode), etc. as indicated by July 10, 1996, the Japan Society of Applied Physics issuance, "volume [of application physics / 65th] No. 7", and p676-p686.
[0003] As a nitride semi-conductor, gallium nitride (GaN), alumimium nitride (AlN), nitriding in JUUMU (InN), etc. have an III-V group nitride system compound semiconductor as indicated by this reference. Since it is possible to make it change in the range whose band gap is 1.95-6.0eV as for these nitrides semi-conductor, it can expect application to the light emitting device which covers the wavelength field from red to ultraviolet. Moreover, since it has the band structure of a direct transition mold in addition to the property that these nitrides semi-conductors are a high degree of hardness, high-melting, and high temperature conductivity, implementation of high brightness and an efficient light emitting device is expected.
[0004] A nitride semi-conductor, for example, GaN, has the melting point as high as

1700 degrees C, and since the equilibrium vapor pressure of nitrogen is moreover high, melt growth (bulk crystal growth) is difficult for it. For this reason, like a publication in said reference, sapphire (aluminum 2O3) etc. is used as a growth substrate, and on it, epitaxial growth of the GaN which is a crystal thin film is carried out, and it is formed. as an epitaxial grown method -- halide gaseous-phase epitaxy (HVPE) -- law and organic metal chemical reaction growth (MOCVD) -- law and organic metal molecular-beam growth (MOMBE) -- law and RF induction molecular-beam growth (RF-MBE) -- law etc. is known. Moreover, if it considers as the growth substrate of a nitride semi-conductor, gallium arsenide (GaAs), carbonization silicon (SiC), silicon (Si), etc. can think.

[0005] It is common knowledge that originate in a substrate and a growth phase (misfit: f), for example, a lattice constant difference with GaN, the crystallinity of a growth phase gets worse in the case of this epitaxial growth, and conductivity control of p mold by installation of an impurity or n mold becomes difficult. For example, if GaN is taken for an example, the misfit f, such as GaN, aluminum 2O3, GaAs, and Si, will exceed 15% very greatly. On the other hand, in SiC, the misfit f with a nitride semi-conductor is about 2% small as given also in said reference. For this reason, it is possible to grow up the crystal thin film of a direct nitride semi-conductor on a SiC substrate.

[0006] In the combination of a substrate (for example, aluminum 2O3, GaAs, Si) and a nitride semi-conductor with which Misfit f exceeds 10%, a thin film suitable between a substrate and a growth phase is inserted in said reference as a publication, and a means to aim at relaxation of Misfit f is taken. It enables this to obtain a good epitaxial growth phase.

[0007] It is known that the above mentioned misfit f of aluminum 2O3 and GaAs etc. is comparatively easy surface treatment in a large substrate, a buffer layer is formed in the surface layer, and the crystal thin film of a good nitride semi-conductor can be grown up on the buffer layer. For example, aluminum 2O3 In formation of the nitride semi-conductor thin film to a substrate top, it also sets to which grown method of the HVPE, MOCVD, MOMBE, or RF-MBE method, and is aluminum 2O3 about a nitrogen raw material. By irradiating a substrate front face, it is aluminum 2O3. The **** alumimium nitride (AlN) film can be extremely formed on the front face of a substrate. This AlN film is minded and the crystal thin film of nitride semi-conductors, such as GaN, AlN, and InN, is aluminum 2O3. It is formed on a substrate.

[0008]

[Problem(s) to be Solved by the Invention] As mentioned above, on a SiC substrate, they are direct and aluminum 2O3. On a substrate or a GaAs substrate, the crystal thin film of a nitride semi-conductor is formed through the AlN film. However, if a cheap substrate can be used like Si substrate, convenience on cost competitiveness is good.

[0009] However, if it is going to use Si as a substrate, the front face of Si substrate makes it amorphous by the exposure to Si substrate of the department of nitrogen Hara, and growth of the nitride semi-conductor thin film of a good single crystal is very difficult. Therefore, in order to grow up the crystal thin film of a nitride semi-conductor on Si substrate, it is necessary to deposit the crystal thin film of a nitride semi-conductor using the substrate which deposited beforehand the SiC film and the GaAs film with a thickness of several microns on Si substrate, and deposited this SiC film and GaAs film with the above mentioned epitaxial grown method.

[0010] However, by the approach using the substrate to which epitaxial growth of such SiC film or the GaAs film was carried out, in order that an epitaxial growth process

may cover multiple times, a production process becomes complicated.
[0011] Moreover, the crystal thin film of the nitride semi-conductor which grew on it thickly [the thickness of the SiC film on Si substrate or the GaAs film] since the quality was not necessarily enough also has the fault that it is the imperfect film.
[0012] Furthermore, conventional aluminum 2O3 If the crystal structure serves as hexagonal system and, as for nitride semi-conductors, such as GaN by which epitaxial growth was carried out on the field (0001) of a substrate, takes into consideration the workability of a thin film, and the ease of a production process, as for the crystal structure of a nitride semi-conductor, it is desirable that it is cubic system.
[0013] The object of this invention is faced carrying out epitaxial growth of the crystal thin film of a nitride semi-conductor on Si substrate, and is to prevent amorphous-ization of Si substrate front face.
[0014] Other objects of this invention are to offer the technique of the good middle class (buffer layer) who can do epitaxial growth of the crystal thin film of a good nitride semi-conductor on Si substrate.
[0015] The object of further others of this invention is to simplify said interlayer's formation process.
[0016] The object of further others of this invention is to offer the technique which can form the crystal thin film of a good nitride semi-conductor on Si substrate.
[0017] The object of further others of this invention is to offer the technique which chooses which the crystal structure of cubic system or hexagonal system as arbitration, and can form the crystal thin film of a nitride semi-conductor on Si substrate.
[0018] The other objects and the new description will become clear from description and the accompanying drawing of this description along [said] this invention.
[0019]
[Means for Solving the Problem] It will be as follows if the outline of a typical thing is briefly explained among invention indicated in this application.
[0020] (1) It is characterized by for the semiconductor device of this invention being a semiconductor device which has a single crystal silicon substrate, an interlayer on a silicon substrate, and the nitride semi-conductor layer by which epitaxial growth was carried out on the interlayer, and being what controls amorphous-ization by nitriding of the silicon substrate in the case of epitaxial growth, while this interlayer eases the lattice constant difference of a silicon substrate and a nitride semi-conductor layer.
[0021] According to such a semiconductor device, existence of an interlayer enables it to form a good nitride semi-conductor layer on a cheap silicon substrate. That is, since an interlayer is what controls amorphous-ization of the silicon substrate surface in the case of epitaxial growth while easing the lattice constant difference of a silicon substrate and a nitride semi-conductor layer, he makes possible epitaxial growth of a nitride semi-conductor layer, and prevents crystalline aggravation of the nitride semi-conductor layer by the mismatching of a lattice constant.
[0022] Moreover, an interlayer can be taken as the carbonization silicon film or silicon germanium film which has the crystal structure. Thus, by using an interlayer as the crystal thin film of the carbonization silicon film or the silicon germanium film, the mismatching of a lattice constant is eased and an interlayer's amorphous-ization can be prevented.
[0023] Moreover, an interlayer's thickness can be set to 10nm or less. Thereby, an interlayer's surface surface smoothness is improved and the crystallinity of a nitride semi-conductor layer can be made good. That is, although it will originate in

aggravation of the shape of an interlayer's surface type and the crystallinity of a nitride semi-conductor layer will fall if an interlayer's thickness becomes thick, the above nonconformities can be controlled by setting an interlayer's thickness to 10nm or less.
[0024] Moreover, when the crystal structure of an interlayer and a nitride semi-conductor layer can be made into cubic system when the front face of a silicon substrate is physically used as an equivalent front face with a field (100), and the front face of a silicon substrate is physically used as an equivalent front face with a field (111), the crystal structure of an interlayer and a nitride semi-conductor layer can be made into hexagonal system. Thus, in the semiconductor device of this invention, it can have the crystal structure of a nitride semi-conductor layer for any of cubic system or hexagonal system being by choosing field bearing of the front face of a silicon substrate. When the crystal structure of a nitride semi-conductor layer is made into cubic system, the workability improves and it becomes possible to simplify a production process.
[0025] Moreover, the lattice constant difference of an interlayer and a nitride semi-conductor layer can be made into 5% or less. If a lattice constant difference is 5% or less, it will become possible to form the crystal thin film of the nitride semi-conductor which has good crystallinity with epitaxial growth.
[0026] (2) The manufacture approach of the semiconductor device of this invention forms the single crystal thin film which eases the lattice constant difference of a substrate and a nitride semi-conductor layer on the principal plane of a substrate as pretreatment of the process which carries out epitaxial growth of the nitride semi-conductor layer on the substrate of single crystal silicon.
[0027] Since the single crystal thin film which eases the lattice constant difference of a substrate and a nitride semi-conductor layer is formed according to the manufacture approach of such a semiconductor device, a good nitride semi-conductor layer can be grown epitaxially on the substrate of single crystal silicon. Moreover, since the thin film of a single crystal is formed, amorphous-ization of a silicon substrate surface can be prevented and epitaxial growth of a nitride semi-conductor layer can be made possible.

[0028] This single crystal thin film can be formed by heat-treating a substrate in the ambient atmosphere of the gas which consists of a molecule containing a carbon atom or a germanium atom, and a hydrogen atom. Thus, by heat-treating a substrate in the ambient atmosphere of the gas which consists of a molecule containing a carbon atom or a germanium atom, and a hydrogen atom, the thin film of SiC or SiGe is formed on a silicon substrate as a single crystal thin film, and the single crystal thin film of this SiC or SiGe is operated as the middle class in the case of the epitaxial growth of a nitride semi-conductor layer (buffer layer). Thereby, a good nitride semi-conductor layer can be grown epitaxially on a silicon substrate. Moreover, in this way, SiC on a silicon substrate or the single crystal thin film of SiGe can be formed only by easy heat treatment, and a complicated process like the conventional technique does not need to be used for it. Thereby, a process can be simplified. That is, a single crystal thin film can be formed, using the reactor (reaction vessel) of the epitaxial growth of the nitride semi-conductor layer performed after formation of a single crystal thin film as it is (pretreatment).
[0029] Moreover, the conditions of heat treatment can make the range whose temperature of a substrate is 700 degrees C - 1300 degrees C, and the processing time the range of 1 second - 1 hour. According to this condition, thickness of SiC on a silicon substrate or the single crystal thin film of SiGe can be set to 10nm or less, and

the crystallinity of a nitride semi-conductor layer can be made good.
[0030] Moreover, a substrate can be processed with the acidic solution containing hydrogen before formation of a single crystal thin film. Thereby, termination of the front face of the silicon substrate before formation of a single crystal thin film can be carried out by the hydrogen atom, and the cleanliness can be held.
[0031] Moreover, a nitride semi-conductor layer can be formed using the halide gaseous-phase epitaxy method, an organic metal chemical reaction grown method, an organic metal molecular-beam grown method, or the molecular-beam-epitaxy method that used the source of a nitrogen radical. That is, if the single crystal thin film (interlayer) of this invention is used, it is possible for it not to be necessary to limit the formation approach of a nitride semi-conductor layer, and to adopt all epitaxial grown methods especially.
[0032]
[Embodiment of the Invention] Hereafter, the gestalt of operation of this invention is explained to a detail based on a drawing.
[0033] (Gestalt 1 of operation) Drawing 1 is the sectional view having shown the process until it deposits the gallium nitride film on the silicon substrate of the semiconductor device of the gestalt of this operation.
[0034] The gestalt of this operation explains the process which passes through and carries out terrorism epitaxial growth of the gallium nitride film on Si substrate as an example of a typical nitride semi-conductor layer.
[0035] First, the Si substrate 4 with field bearing of (001) is prepared, and a suitable approach cleans a front face chemically (drawing 1 R> 1 (a)). The natural oxidation film 5 is formed in the front face of the Si substrate 4 in this condition.
[0036] Next, the Si substrate 4 is dipped into 1% of HF water solution, and chemical cleaning is performed (drawing 1 (b)). By this, while removing the natural oxidation film 5 of the front face of the Si substrate 4, the joint hand of a surface silicon atom forms the hydrogen termination side 6 by which termination was carried out from hydrogen. This hydrogen termination side 6 holds the cleanliness of the front face of the Si substrate 4, and functions as a kind of protective coat.
[0037] Next, the Si substrate 4 is introduced in molecular-beam crystal growth (MBE) equipment, and the single crystal SiC thin film 7 of about 2nm thickness is formed in the front face of the Si substrate 4 (drawing 1 (c)). In the ambient atmosphere of the ethanol (C2 H5 OH) of about ten to 6 Torr, the Si substrate 4 is heat-treated the condition for the temperature of about 900 degrees C, and 15 minutes, and formation of the single crystal SiC thin film 7 forms it.
[0038] Such a single crystal SiC thin film 7 eases the difference (misfit f) of the lattice constant of the GaN film 8 and the lattice constant of the Si substrate 4 which are formed at degree process. That is, although Misfit f becomes 15% or more and the epitaxial growth of the good GaN film cannot be expected when it is going to deposit the direct GaN film 8 on the Si substrate 4, the misfit f of the single crystal SiC thin film 7 and the GaN film 8 becomes about 2%, and it becomes possible to form the crystalline good GaN film 8 on the Si substrate 4.
[0039] Moreover, the single crystal SiC thin film 7 has the function to prevent amorphous-ization of Si substrate 4 front face by deposition of the GaN film 8 of degree process. Thereby, the difficulty of the epitaxial growth of the GaN film 8 resulting from amorphous-ization of Si substrate 4 front face is avoidable. That is, inhibition of amorphous-izing and the effectiveness of relaxation of Misfit f become possible [forming the good GaN film 8 on the cheap Si substrate 4 conjointly].

[0040] Thus, according to examination of this invention person, it is considered that the single crystal SiC thin film 7 is formed of a mechanism [like] below that the good GaN film 8 can be formed on the Si substrate 4 although based on it being a single crystal thin film with the good single crystal SiC thin film 7. namely, the reaction by which the clean surface is held since the front face of the Si substrate 4 is covered with the hydrogen termination side 6, and the carbon in ethanol and the hydrogen of the hydrogen termination side 6 are permuted by said heat treatment -- being generated -- the front face of the Si substrate 4 -- **** -- a thin (about 2nm) SiC thin film is formed. such **** -- since it is what is not formed of deposition reactions, such as CVD, and is formed of adhesion in the front face of the Si substrate 4, and a substitution reaction, a thin SiC thin film is formed as a good single crystal thin film reflecting the crystallinity of the Si substrate 4.
[0041] Moreover, the single crystal SiC thin film 7 is formed in the front face of the Si substrate 4 of the easy above heat treatments, and heat treatment is performed within the molecular-beam crystal growth (MBE) equipment for forming the GaN film 8. Thereby, the single crystal SiC thin film 7 can be formed simple not as the process in the independent thermal treatment equipment but as pretreatment of the molecular-beam crystal growth process of degree process. Consequently, the good GaN film 8 can be formed on the cheap Si substrate 4 according to a simple heat treatment process, without adopting a complicated process to which epitaxial growth of the thick SiC film or the GaAs film is carried out on the Si substrate 4.
[0042] In addition, although the case of about 2nm was illustrated as thickness of the single crystal SiC thin film 7, as long as the single crystal SiC thin film 7 is formed as uniform film on the Si substrate 4, even if still thinner, it does not care about (thickness of monoatomic layer extent). As long as the silicon wafer which can be marketed or manufactured actually is used according to experiment examination of this invention person, about 2nm thickness is required. Since one atomic layer of single crystal SiC thin films 7 is not necessarily formed at a time and they are formed in the shape of an island, if this does not become about 2nm thickness, it is because it does not become the wrap film about all the front faces of the Si substrate 4. However, as long as this invention is not necessarily limited to this thickness 2nm or more and the single crystal SiC thin film 7 is formed as film, it is as aforementioned that the thickness of monoatomic layer extent is sufficient.
[0043] Moreover, as for the thickness of the single crystal SiC thin film 7, it is desirable that it is 10nm or less. According to experiment examination of this invention person, formation of the single crystal SiC thin film 7 is formed when adhesion of a carbon atom and a substitution reaction with a hydrogen atom arise as aforementioned, but a silicon atom will be supplied from the Si substrate 4. From the Si substrate 4, is not necessarily supplied to homogeneity and supply of this silicon atom not necessarily tends to be selectively supplied from a certain specific field (to ununiformity). For this reason, if a pit-like crevice is formed in this specific field and the thickness of the single crystal SiC thin film 7 becomes thick, this crevice will be expanded and the surface mol follow G of the single crystal SiC thin film 7 will deteriorate. This also means crystalline degradation of the single crystal SiC thin film 7. According to examination of this invention person, the level of the irregularity of the permissible single crystal SiC thin film 7 is extent with which the thickness of the single crystal SiC thin film 7 is equivalent to 10nm. For this reason, it will be desirable that the thickness of the single crystal SiC thin film 7 is 10nm or less.
[0044] Next, the GaN film 8 is deposited by the molecular-beam crystal growth method

(drawing 1 (d)). Deposition of the GaN film 8 makes material gas for example, organic gallium gas and ammonia (NH3), is substrate temperature [of 600 degrees C], and reaction-time 1 hour, and carries out epitaxial growth to the thickness of 50nm. Growth rates are about 50 nm/h. Thus, the heteroepitaxial growth film of GaN which is illustrated is manufactured.

[0045] At this process, since the single crystal SiC thin film 7 is formed of the above mentioned pretreatment, the front face of the Si substrate 4 is nitrided with the ammonia which is reactant gas of the GaN film 8, and it is not made amorphous. Moreover, the crystallinity can be made good even if it is the GaN film 8 formed on the Si substrate 4, since the single crystal SiC thin film 7 with which Misfit f is eased is formed. Therefore, conductivity control of p mold by the impurity installation to the nitride semi-conductor layer formed in the GaN film 8 or its upper layer or n mold is possible, and it is possible to apply to an efficient and highly efficient component.

[0046] In addition, although the example which forms the GaN film 8 by the molecular-beam crystal growth method was shown, it can form here using other epitaxial grown methods, for example, the halide gaseous-phase epitaxy method, an organic metal chemical reaction grown method, or the molecular-beam-epitaxy method using the source of a nitrogen radical.

[0047] Then, the compound semiconductor layer of the GaN system of arbitration is formed, and LED of double hetero structure, LED of single quantum well (SQW) structure, or LD of multiplex quantum well (MQW) structure can be formed.

[0048] If the manufacture approach of the semiconductor device of the gestalt this operation is used, the GaN film 8 which has good crystallinity can be formed simple on the cheap Si substrate 4.

[0049] Drawing 2 and drawing 3 show the crystal assessment result of the GaN film formed of the gestalt of this operation, drawing 2 is the pattern photograph which observed the reflective high energy electron beam diffraction (RHEED) graphic form, and drawing 3 is the cross-section photograph of an interface part observed with the transmission electron microscope.

[0050] Observation of a reflective high energy electron beam diffraction (RHEED) graphic form performs ** in MBE equipment after growth of the GaN film 8. It turns out that the GaN film 8 by which heteroepitaxial growth was carried out is a single crystal object which has the crystal structure of a cubic (zinc-blend) mold so that clearly from the analysis of this result.

[0051] Moreover, it turns out that SiC to which the cross-section photograph shown in drawing 3 has the thickness of about 2nm in the interface of the GaN film 8 and the Si substrate 4 which are the heteroepitaxial growth film as it is the result of observing the interface part of the GaN film 8 with ejection and a cross-section transmission electron microscope from an MBE room and said Si substrate 4 is shown in drawing is formed, and that formation of an amorphous layer is not seen in the front face of the Si substrate 4. It turns out that it is prevented with the single crystal SiC thin film 7 with which the breakage by the nitrogen raw material exposure at the time of growing epitaxially formed the GaN film 8 previously so that clearly from these observation results. In addition, as for the single crystal SiC thin film 7, it is checked by reflective high energy electron beam diffraction that it is a single crystal.

[0052] (Gestalt 2 of operation) In the gestalt 1 of operation, although the example of formation of the single crystal SiC thin film 7 in an ethanol ambient atmosphere was explained, the SiC thin film of a single crystal is formed into hydrocarbon system gas ambient atmospheres, such as acetylene and ethylene, also except an ethanol ambient

atmosphere. That is, an ambient atmosphere required for formation of the single crystal SiC thin film by heat treatment is realizable with the molecule ambient atmosphere which contains carbon and hydrogen at least. Here, it is checked by this invention person that effect does not arise especially in formation of a single crystal SiC thin film even if it is the molecule which contains oxygen like ethanol. Moreover, in hydrocarbon system gas, a carbonaceous joint format (that is, is it single association or is a double bond?) does not influence especially formation of a single crystal SiC thin film, either.

[0053] Next, heat treatment temperature and the processing pressure force explain to the thickness of a single crystal SiC thin film using a table 1 how it influences in the case of formation of the single crystal SiC thin film in a hydrocarbon system gas ambient atmosphere.

[0054]

[A table 1]

表1

圧力 [Torr] / 温度 [℃]	5×10^{-5}	5×10^{-6}	5×10^{-7}
850	20	−−	−−
900	50	20	−−
950	100	40	20

[0055] A table 1 is a result table of an experiment having shown the difference of the temperature of heat treatment of the thickness of a single crystal SiC thin film [/ in reaction-time 10 minutes] and the pressure of a processing ambient atmosphere. In addition, the unit of thickness is angstrom.

[0056] The thickness of a single crystal SiC thin film becomes thick, so that a pressure is high, and the thickness of a single crystal SiC thin film tends to become thick, so that the temperature of processing is high. Moreover, a pressure is low and the field ("--" shows among a table) in which a single crystal SiC thin film is not formed exists in the field where temperature is low. Thus, since it is dependent on a pressure and time amount, the formation rate of a single crystal SiC thin film can adjust reaction time, and can obtain predetermined thickness. However, thickness becomes large linearly to reaction time, when it is 20nm or less, but if set to 20nm or more, supply of the silicon from a substrate will not be carried out, but thickness will be saturated. In the case of 5x10-5Torr, in the case of 5x10-6Torr, the time amount with which thickness is saturated is about 60 minutes for about 20 minutes for about 10 minutes in the case of 5x10-7Torr.

[0057] In addition, although the case where temperature is 850 degrees C - 950 degrees C is illustrated, it is checking that a single crystal SiC thin film can be formed by selection of reaction pressure in a 700-1300-degree C temperature requirement here. Moreover, although it is as aforementioned that the thickness of a single crystal SiC thin film can be formed to about 20nm, the range of the optimal thickness is 2nm - 10nm. Therefore, the optimal thickness can be chosen based on said experimental result, and reaction time can be made into the range of 1 second - 1 hour.

[0058] (Gestalt 3 of operation) Drawing 4 is the sectional view having shown an example of the light emitting diode which is the gestalt of other operations of this invention. The light emitting diode (LED) of the gestalt 3 of this operation It has single quantum well (SQW) structure. On the single crystal silicon substrate 11 It has the interlayer 12 who consists of a single crystal SiC thin film which was explained with the

gestalten 1 and 2 of operation, the n mold GaN barrier layer 13, the undoping InGaN well layer 14, the p mold AlGaN barrier layer 15, and the p mold GaN contact layer 16. In contact with the n mold GaN barrier layer 13, the p electrode 18 is formed in contact with the n electrode 17 and the p mold GaN contact layer 16.
[0059] In such LED, since the interlayer 12 who can constitute cheaply using the single crystal silicon substrate 11, and consists of a single crystal SiC thin film is formed in the interface of the single crystal silicon substrate 11 and the n mold GaN barrier layer 13, the crystallinity of the undoping InGaN well layer 14 formed in the n mold GaN barrier layer 13 and its upper layer, the p mold AlGaN barrier layer 15, and the p mold GaN contact layer 16 can be formed good. Consequently, the crystallinity of the undoping InGaN well layer 14 grade which is a barrier layer is made good, and efficient and quality LED can be constituted.
[0060] In addition, the approach of forming the interlayer 12 who consists of a single crystal SiC thin film, and the n mold GaN barrier layer 13 on the single crystal silicon substrate 11 is the same as that of the case where the single crystal SiC thin film 7 and the GaN film 8 of gestalten 1 or 2 of operation are formed. moreover, formation of the undoping InGaN well layer 14, the p mold AlGaN barrier layer 15, and the p mold GaN contact layer 16 -- the n mold GaN barrier layer 13 -- the same -- MBE -- it can carry out using law.
[0061] (Gestalt 4 of operation) Drawing 5 is the sectional view having shown an example of the semiconductor laser of this invention which is the gestalt of other operations further. The semiconductor laser (LD) of the gestalt 4 of this operation has multiplex quantum well (MQW) structure. On the single crystal silicon substrate 11 The gestalt 1 of operation And the interlayer 12 who consists of a single crystal SiC thin film which was explained by 2, the n mold GaN contact layer 19, the n mold InGaN crack prevention layer 20, the n mold AlGaN cladding layer 21, the n mold GaN guide layer 22, the InGaN luminous layer 23, the interior cladding layer 24 of p mold AlGaN, It has the p mold GaN guide layer 25, the p mold AlGaN cladding layer 26, and the p mold GaN contact layer 27, and the p electrode 29 is formed in contact with the n electrode 28 and the p mold GaN contact layer 27 in contact with the n mold GaN contact layer 19.
[0062] It can constitute from such LD cheaply like the gestalt 3 of operation using the single crystal silicon substrate 11. Moreover, since the interlayer 12 who consists of a single crystal SiC thin film is formed in the interface of the single crystal silicon substrate 11 and the n mold GaN contact layer 19, The n mold GaN contact layer 19 And the n mold InGaN crack prevention layer 20 formed in the upper layer, the n mold AlGaN cladding layer 21, the n mold GaN guide layer 22, the InGaN luminous layer 23, the interior cladding layer 24 of p mold AlGaN, the p mold GaN guide layer 25, the p mold AlGaN cladding layer 26 And the crystallinity of the p mold GaN contact layer 27 can be formed good. Consequently, the crystallinity of the InGaN luminous layer 23 grade which is a MQW layer is made good, and efficient and quality LD can be constituted.
[0063] In addition, the approach of forming the interlayer 12 who consists of a single crystal SiC thin film, and n mold GaN contact layer 19 grade on the single crystal silicon substrate 11 is the same as that of the gestalt 3 of operation. moreover, formation of n mold GaN contact layer 19 grade -- the gestalt 3 of operation -- the same -- MBE -- it can carry out using law.
[0064] As mentioned above, although invention made by this invention person was concretely explained based on the gestalt of implementation of invention, it cannot be

overemphasized that it can change variously in the range which this invention is not limited to the gestalt of said operation, and does not deviate from the summary.
[0065] For example, with the gestalt of said operation, although the SiC film was formed by heat treatment, you may form by the spatter using a SiC raw material etc.
[0066] Moreover, although the gestalt of said operation explained the case where field bearing of Si substrate was a field (001), which field bearings other than a field (001) may be used. It has become clear by experiment of this invention person that bearing of SiC also changes according to field bearing of Si substrate, and the crystal structure of the GaN film 8 also changes from a cubic to hexagonal (hexagonal) further again.
[0067] Furthermore, with the gestalt of said operation, although the heteroepitaxial growth of the GaN film was mainly explained, a compound not only with this but the AIN film, the InN film and these and an III group element, or IV group element etc. is widely applicable also to the heteroepitaxial growth of other nitride semi-conductor film.
[0068] Moreover, although the case of the SiC film was illustrated as an interlayer, it may replace with this and the SiGe thin film of a single crystal may be applied. The same effectiveness as the above is acquired also in this case.
[0069] Moreover, in the gestalten 3 and 4 of operation, although the case where it applied to a light emitting device was explained, it is not restricted to this but you may apply to semiconductor devices, such as IC.
[0070]
[Effect of the Invention] It will be as follows if the effectiveness acquired by the typical thing among invention indicated in this application is explained briefly.
[0071] (1) It faces carrying out epitaxial growth of the crystal thin film of a nitride semi-conductor on Si substrate, and while easing the mismatching of a lattice constant difference, amorphous-ization of Si substrate front face can be prevented.
[0072] (2) The good middle class (buffer layer) who can do epitaxial growth of the crystal thin film of a good nitride semi-conductor on cheap Si substrate can be offered.
[0073] (3) An interlayer can be formed simple.
[0074] (4) The crystal thin film of a good nitride semi-conductor can be formed on Si substrate.
[0075] (5) Which the crystal structure of cubic system or hexagonal system is chosen as arbitration, and the crystal thin film of a nitride semi-conductor can be formed on Si substrate.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] (a) - (d) is the sectional view having shown the process until it deposits the gallium nitride film on the silicon substrate of the semiconductor device which is the gestalt of 1 operation of this invention.
[Drawing 2] It is the pattern photograph which showed the crystal assessment result of the GaN film formed with the gestalt 1 of operation, and observed the reflective high energy electron beam diffraction (RHEED) graphic form.
[Drawing 3] It is the cross-section photograph of an interface part which showed the crystal assessment result of the GaN film formed with the gestalt 1 of operation, and was observed with the transmission electron microscope.
[Drawing 4] It is the sectional view having shown an example of the light emitting diode which is the gestalt of other operations of this invention.
[Drawing 5] It is the sectional view having shown an example of the semiconductor laser of this invention which is the gestalt of other operations further.
[Description of Notations]
4 Si Substrate
5 Natural Oxidation Film
6 Hydrogen Termination Side
7 Single Crystal SiC Thin Film
8 GaN Film
11 Single Crystal Silicon Substrate
12 Interlayer
13 N Mold GaN Barrier Layer
14 Undoping InGaN Well Layer
15 P Mold AlGaN Barrier Layer
16 P Mold GaN Contact Layer
17 28 n electrode
18 29 p electrode
19 N Mold GaN Contact Layer
20 N Mold InGaN Crack Prevention Layer
21 N Mold AlGaN Cladding Layer
22 N Mold GaN Guide Layer
23 InGaN Luminous Layer
24 Interior Cladding Layer of P Mold AlGaN
25 P Mold GaN Guide Layer
26 P Mold AlGaN Cladding Layer
27 P Mold GaN Contact Layer
f Misfit

[Translation done.]

the original precisely.

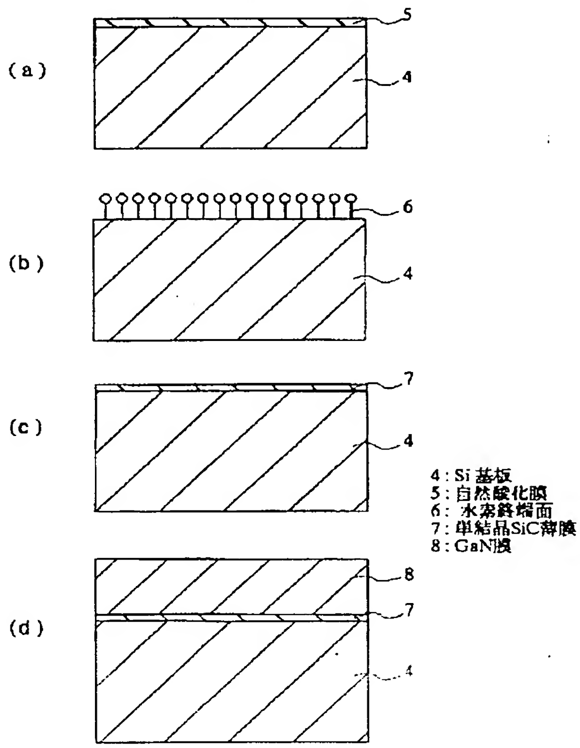
2.**** shows the word which can not be translated.

3.In the drawings, any words are not translated.

DRAWINGS

[Drawing 1]

図 1

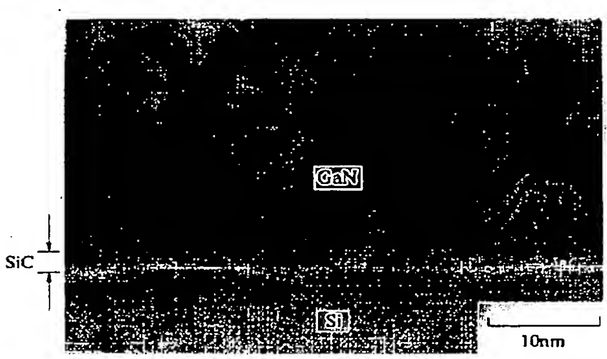


[Drawing 2]

図 2

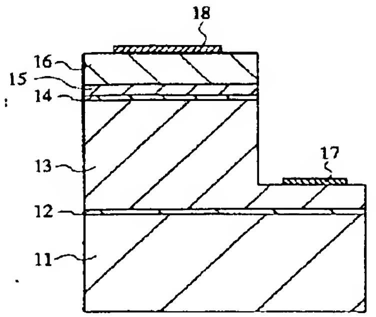
[Drawing 3]

図 3



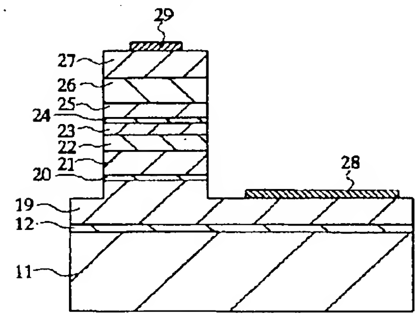
[Drawing 4]

図 4



[Drawing 5]

図 5



[Translation done.]